

Mir Principal Expedition 18

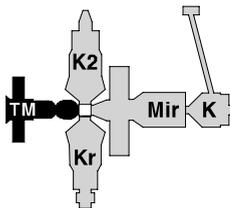
Commander Vladimir Dezhurov (1st flight)
 Flight engineer Gennadiy Strekalov (5th)
 Cosmonaut-Researcher Norman Thagard
 (U.S. astronaut) (5th)
 Code name Uragan
 Launched in Soyuz-TM 21, March 14, 1995
 Landed in Space Shuttle Orbiter Atlantis,
 July 7, 1995
 115 days in space

Highlights: The major objectives of the Mir 18 mission were to conduct joint U.S.-Russian medical research and weightlessness effects investigations and to reconfigure the station for the arrival of the Spektr science module and the Space Shuttle Atlantis. The historic mission saw the addition of the first new module (Spektr) since Kristall arrived in 1990, the first American (Thagard) to be part of a Mir crew, and the first docking of a U.S. spacecraft with the Mir complex.

Soyuz-TM 21 launches new crew. On March 14, Soyuz-TM 21 launched from Baikonur with Dezhurov, Strekalov, and Thagard set to relieve the Mir 17 crew. Three hours after launch, the cosmonauts began a series of maneuvering burns to bring Soyuz-TM 21 to a rendezvous orbit. During the 2-day trip, they checked systems and collected biomedical data on the effects of microgravity on the human body.²³

Record number of humans in orbit. The launch of the Mir 18 crew brought to thirteen the number of men and women in space at the same time. This new record included the Mir 17 and 18 crews of three each and the STS-67 crew of seven aboard the Space Shuttle Endeavour, launched March 2. (Endeavour landed at Edwards Air force Base on March 18, surpassing previous Space Shuttle mission durations with its 16 days, 15 hr, and 08 min in space.)

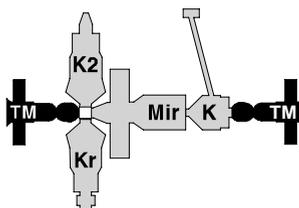
March 15-16, 1995



Kvant 2
Soyuz-TM 20 - Mir - Kvant
Kristall

Progress-M 26 clears Kvant docking port for new Soyuz-TM. Progress-M 26 separated from the complex on March 15 and made a destructive reentry into the Earth's atmosphere.

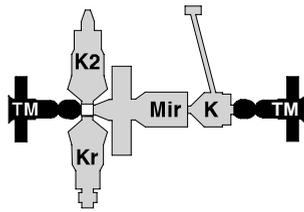
March 16-22, 1995



Kvant 2
Soyuz-TM 20 - Mir - Kvant - Soyuz-TM 21
Kristall

New Soyuz-TM 21 docks. Soyuz-TM 21 docked by automatic control at the Kvant docking port on the first try at 0745 UTC March 16.²⁴ The new arrivals were greeted by the Mir 17 crew with traditional Russian gifts of salt and bread, and shortly thereafter were congratulated on a successful docking and transfer by Russian Space Agency (RSA) Director General Yuri Koptev and NASA Associate Administrator Wayne Little. The crew spent much of the day transferring equipment and supplies from Soyuz to Mir. Thagard spoke with STS-67 Commander Steve Oswald in a radio hookup, exchanging congratulations on their respective

March 16-22, 1995



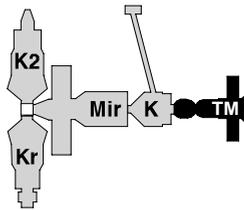
Concluded

flights and discussing the symbolic importance of Thagard's venture as the first American to visit Mir.²⁵

More congratulations. On March 17, Russian Prime Minister Viktor Chernomyrdin stopped by the TsUP to congratulate the crew. Later, in a televised communication with ground controllers, Thagard said he hoped his visit to Mir would be the start of long-term space cooperation between the two nations. He and Polyakov agreed that the present joint research might be the foundation for ultimate joint flights to Mars.²⁶

Joint crew occupancy. During the next few days, the Mir 18 crew took their body mass measurements as a baseline for investigations throughout the mission and were briefed by the Mir 17 crew on the status of the complex and ongoing studies. The outgoing crew stowed equipment and experiment samples in Soyuz-TM 20 for their return and checked out the vehicle systems.²⁷

**March 22, 1995 -
April 11, 1995**

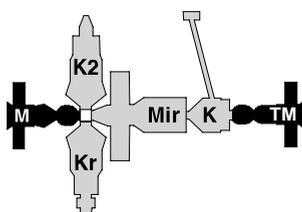


**Kvant 2
Mir - Kvant - Soyuz-TM 21
Kristall**

Mir 17 mission ends. Viktorenko, Kondakova, and Polyakov entered Soyuz-TM 20 on March 21 and departed from Mir on March 22, landing safely on the same day about 50 km from Arkalyk, Kazakhstan. Polyakov had set a new record for space-flight duration: he had been on Mir since January 8, 1994—for 438 straight days. This trip, added to his Mir stay in 1988, brought his total days in space to 679. He was, however, strong enough to walk to the chairs that rescue crews provided for the cosmonauts' transport to a field hospital. He said his fit condition was a positive indication that humans could withstand a trip to Mars.²⁸

Mir 18 crew on their own. The Mir 18 crew settled into their daily routine, collecting body fluid samples for the seven metabolic experiments to be performed during their mission. They also took air and water samples for four hygiene, sanitation, and radiation experiments which would determine the role of the Mir environment in human health, safety, and efficiency.²⁹ Each crewman spent time in the Chibis suit for measurement of cardiovascular system responses to lower body negative pressure. In the absence of gravity, blood pools in the upper torso and head, causing cardiovascular deconditioning. The Chibis suit seals at the waist and incrementally induces a partial vacuum, or negative pressure, which draws body fluids back to the lower extremities. Dezhurov and Strekalov also changed out a condenser in the air conditioning system, part of a long-term maintenance program to prolong the life of the station.³⁰

April 11 - May 22, 1995



Kvant 2

Progress-M 27 - Mir - Kvant - Soyuz-TM 21

Kristall

Progress-M 27 goes to Mir. Progress-M 27 was launched from Baikonur on April 9. It docked with the Mir base block on April 11 at 21:00 UTC under flawless control by the automatic Kurs system, although Dezhurov was ready to take over by manual control if Kurs malfunctions recurred.³¹ This Progress module carried with it a Raduga return capsule.

Cosmonautics day observed on April 12. On the 34th anniversary of Yuri Gagarin's flight in a Vostok capsule, the Mir crew had a light schedule for Cosmonautics Day, a Russian national holiday. Activities included press conferences through the Russian and U.S. mission control centers.³²

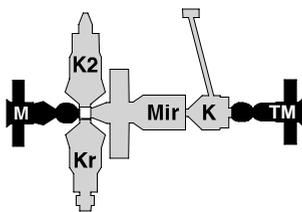
Progress cargo unloaded. On April 13, the crew began unloading the Progress cargo of food, water, fuel, repair materials for life support systems, and equipment for medical and environmental research. Among the biological experiments were some Japanese quail eggs. These, the crew put into an incubator on April 14.³³

GFZ-1 microsatellite launched from Mir. Progress-M 27 also brought a new international experiment in the form of GFZ-1, a spherical satellite with a mass of 20 kg and a diameter of 21 cm. The German satellite was built by the German firm Kayser-Threde. Geoforschungszentrum Potsdam would coordinate the satellite's transmission of geodetic measurements by means of laser reflection to about 25 observatories around the globe. GFZ-1 was successfully launched by the Mir crew from the base block airlock on April 19. (Two days before, the crew had launched a container with garbage as a practice run for the operation.)³⁴

Interior station work. Late in April, the crew learned that extravehicular activities (EVAs) for solar array work, scheduled to start on April 28, had been postponed due to a delay in launch of the Spektr module. (One reason for the delay was that equipment to interface with Mir's manual control system was added to Spektr in case the Kurs system failed again.)³⁵ The crew continued routine experiment work, defrosted the ESA freezer, replaced a humidity control fan with one from Progress-M 27, installed a battery unit in the Kristall module, and began removing an unused shower in the Kvant module to make room for a new set of gyrodynes to support the upcoming Atlantis docking. They dismantled the shower and cut it into small pieces for stowage on the Progress module, then installed the gyrodynes.³⁶

Injury jeopardizes EVA plans. ITAR-TASS reported on May 5 that Strekalov had scratched his hand earlier during cleaning tasks. The scratch became inflamed and caused some concern about Strekalov's ability to do the EVA work. Medical specialists on the ground viewed downlink video of the hand and prescribed

April 11 - May 22, 1995



Concluded

a medication to be administered by Thagard. The injury healed and EVA plans proceeded.³⁷

EVA preparations. In the first week of May, the cosmonauts began preparing their EVA equipment and Orlan-DMA suits, taking inventory of connectors and cables needed for the EVA, and checking out communications systems. They installed power cables between Kvant and Kristall for transmission of power from the solar array that they would move from Kristall to Kvant on their second space walk. The Kristall batteries would be left in that module and would receive solar power through the new cables.³⁸

First Mir 18 EVA. On May 12, Dezhurov and Strekalov began their first EVA to prepare the station for Spektr's arrival, exiting the Kvant 2 airlock at 4:20 UTC and transferring to the Kvant astrophysics module by means of the Strela boom. There they installed electrical cable attachments and adjusted solar array actuators. Then they moved to Kristall and practiced folding three panels of the solar array to be moved to Kvant. Thagard supported the crew from inside Mir by relaying instructions from the ground or from reference manuals when the station was not in range of ground communications.³⁹ Lasting 6 hr and 15 min, the excursion had already exceeded the allotted time, so a third scheduled task, removal of American experiment TREK's space radiation detectors, had to be postponed until the next space walk.⁴⁰

Problems on second EVA. In their second space walk, on May 17, the cosmonauts successfully folded the solar array panels, assisted by Thagard, who controlled servomotor switches from inside Kristall. The spacewalkers disconnected the array from Kristall, attached it to the Strela boom, and moved it to Kvant. The work took so much time that, having already almost used the oxygen available through their suits, they were forced to secure the array to Kvant with tool tethers and postpone electrical connection. Even so, the EVA lasted 6 hr and 52 min.^{41,42} Power supply inside the station suffered without the connection of the array, necessitating interim augmentation by Progress-M 27 and Soyuz-TM 21 solar arrays.⁴³

Spektr launch. The Spektr science module was launched from Baikonur atop a Proton-K rocket at 3:33 UTC on May 20. The initial orbit was 337 by 221 km, period 89.8 min. In the 13 days until the docking of Spektr, the crew would be busy reconfiguring the complete to accommodate the new module.

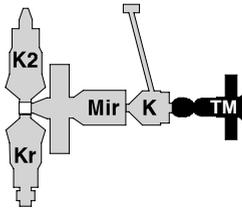
Solar array redeployed in Mir 18 third EVA. On their May 22 walk of 5 hr, 15 min, Dezhurov and Strekalov successfully connected the solar array to Kvant, and Thagard commanded its redeployment from inside the station. The cosmonauts then returned to Kristall, where they retracted 13 panels of another solar array to provide clearance for rotation of Kristall during its relocation to make room for Spektr. Approximately 60% of that array was still available as a power source.⁴⁴

May 22-26, 1995

Kvant 2

Mir - Kvant - Soyuz-TM 21

Kristall



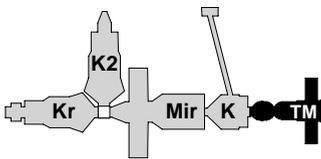
Progress-M 27 frees -X port. Progress-M 27 left Mir at 23:42 UTC on May 22 and made a destructive reentry into the Pacific on May 23. Thus the -Y port was freed for use in the multiple module relocation that would be necessary for the docking and ultimate permanent placement of Spektr.

Preparation for Kristall shifts. The crew began moving umbilicals, cables, and control panels for space suit servicing from Kvant 2 to the base block transfer compartment, which would be depressurized and used as the airlock for the next two EVAs.⁴⁵

May 26-30, 1995

Kvant 2

Kristall - Mir - Kvant - Soyuz-TM 21

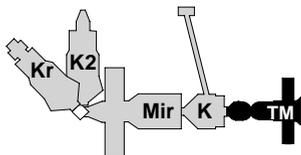


First Kristall move and fourth EVA. From inside the station, Dezhurov controlled the undocking of Kristall on May 26 from the -Y port (lower lateral port of the base block). Then the module was moved by means of its Lyappa arm to the -X port just vacated by Progress-M 27. Figure 5 shows the configuration on May 26 after the Kristall move. On May 28, in their fourth EVA of the mission, Dezhurov and Strekalov moved a docking cone (Konus), from the -X port to the -Z port to serve as the docking receptacle for Kristall in its next move. The space-suited cosmonauts did this work from inside the depressurized base block transfer compartment.^{46,47}

May 30 - June 1, 1995

Kristall Kvant 2

- Mir - Kvant - Soyuz-TM 21



Second Kristall move. In another undocking and relocation sequence controlled from inside the station, on May 30 Kristall was moved from the -X port to the -Z port. Because of a temporary failure in hydraulic connections, the docking was not successful until the third attempt.⁴⁸

Spektr

Specifications

mass-19640 kg

length-14.4 m

maximum diameter-4.35 m

pressurized vol-61.9 m³

solar array area-132 m²

power output-6.9 kW

Description

The Spektr science module (fig. 4), designed by RKK Energia and built by the Khrunichev factory in Moscow, was the first new permanent module to join the Mir complex since Kristall was added in June 1990.⁴⁹ It was originally intended for addition to the complex in the 1990-1992 time frame.⁵⁰

The module was equipped with orbit correction and rendezvous engines and attitude control and docking thrusters. A Kurs guidance system provided automatic rendezvous and docking guidance. Like all other Mir modules, Spektr has a Lyappa manipulator arm for repositioning the module to other ports after initial docking.

The original module design included two solar panels, but after Mir's power problems became acute, the design was changed to incorporate four solar panels. The pair on the pressurized compartment supplies power for the module's own systems; the V-shaped pair on the unpressurized compartment were added to supplement power to the station complex.

Spektr has an unpressurized compartment (5.6 m long), primarily for autonomous Earth sensors, and a pressurized compartment (8.8 m long) which provides 61.9 m³ of work area. This pressurized area provides experiment accommodations such as electrical connectors, power supply switching units, thermoelectric installation sites, workstations and tables, Velcro pads, and cargo containers. Other items to support the crew as they work in the module are a low-noise headset, a clock, a loudspeaker, and a jet foam fire extinguisher.

Most of the Russian and international experiments and sensors aboard are for Earth observation, orbital environment sampling, and Earth atmosphere analysis. These include

- Astra-2 for atmospheric trace constituent monitoring
- Faza spectrometer for Earth surface studies
- Feniks infrared spectrometer for Earth surface studies
- Grif equipment for studying electromagnetic radiation and charged particle flows
- Komza interstellar gas detector (Swiss)
- Lira instrument complex for atmospheric research
- Mir Infrared Atmospheric Spectrometer (MIRAS) for studying interactions between solar radiation and the Earth's atmosphere, to be deployed on the exterior of the module during an EVA (Belgian-French)
- Pion optical complex for atmospheric research
- Priroda-5 Earth imaging system
- Ryabina-4P cosmic ray sensor

- Taurus system for studying electromagnetic radiation and charged particle flows
- European Space Exposure Facility (ESEF) for sensors that would be installed on the exterior of the module during a Euromir 95 EVA. Until installation, the mounting sites had covers that themselves contained instruments to monitor radiation in the orbital environment.

U.S. equipment aboard was largely for biomedical experiments that would be conducted on Mir 18 by Norm Thagard and on future missions by other American astronauts.^{51,52,53,54,55,56}

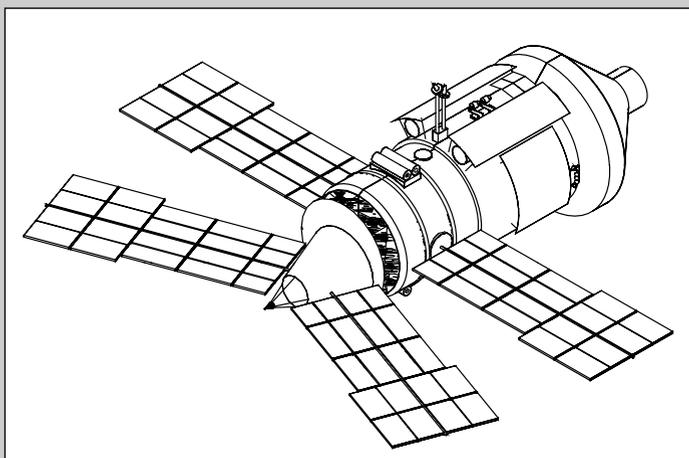


Figure 4a. Spektr, the science module that was added to Mir in May 1995. The module is shown here with solar arrays deployed, a configuration finally achieved on July 14, 1995.

Figure 4b. Spektr after installation. Clouds over Brazil form the backdrop for this 70mm image of the module and other Mir components taken from Atlantis while docked with Mir on March 23, 1996.



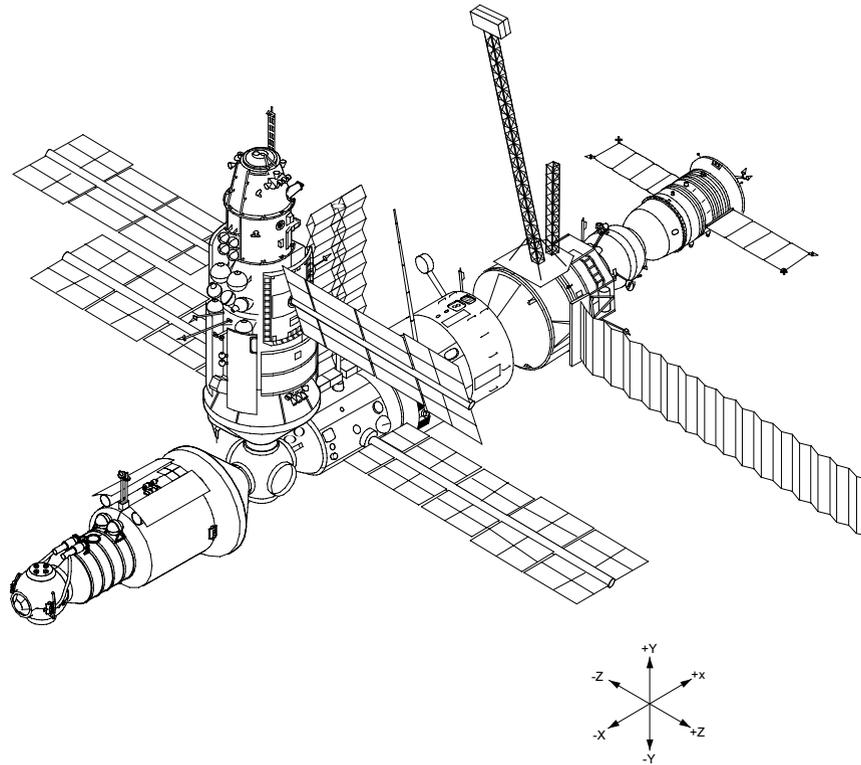
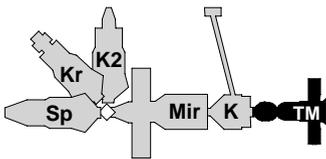


Figure 5. Mir space station configuration on May 26, 1995, after Kristall relocation to the -X port. Kristall is shown without solar arrays, one having been moved to Kvant on May 17, the other retracted on May 22 to provide clearance for Kristall relocation. Port orientations are diagrammed at lower right.

June 1-2, 1995

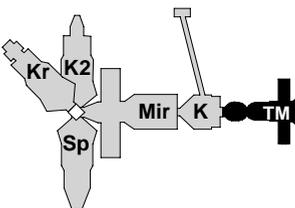
**Kristall Kvant 2
Spektr - Mir - Kvant - Soyuz-TM 21**



Spektr docking and fifth EVA. Despite anxieties about the automatic docking, the Spektr module successfully docked to the -X port under control of the Kurs system on June 1. The next day, in their fifth EVA, the cosmonauts again entered the depressurized base block transfer compartment and moved the Konus from the -Z to the -Y port.⁵⁷

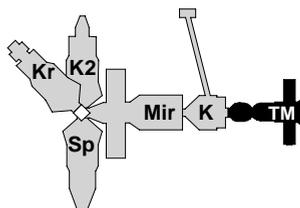
June 2-10, 1995

**Kristall Kvant 2
- Mir - Kvant - Soyuz-TM 21
Spektr**



Spektr relocated. With the Mir crew and TsUP ground controllers in joint control of the Spektr Lyappa arm, the module was moved to the -Y port on June 2.

June 2-10, 1995

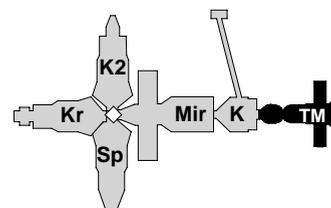


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Spektr solar array fails to extend fully. After the redocking, the crew began checking out and activating the new module's systems and transferring new supplies of food, fuel, and equipment from Spektr to other parts of the complex. On June 5, one of Spektr's four solar arrays failed to fully unfurl because a restraint that held it in place for launch failed to release, and the crew was unable to extend it by sending pulses of power to the motor or by firing Mir's thrusters. TsUP controllers, aided by videos transmitted to them by the crew, began plans for a sixth EVA so that the cosmonauts could release the stuck array.⁵⁸

Thagard surpasses previous American record. Norm Thagard held a press conference on June 6, the day he surpassed the long-held record of U.S. human spaceflight duration of 84 days (set by the Skylab 4 crew from November 16, 1973 to February 8, 1974).⁵⁹

June 10-29, 1995



Kvant 2

**Kristall - Mir - Kvant - Soyuz-TM 21
Spektr**

Kristall relocated again. Before its last scheduled move of the Mir 18 mission, the cosmonauts had to install two new batteries in Kristall to boost its power supply enough to accomplish the undocking and redocking.⁶⁰ Then on June 10, the module was undocked from the -Z port, and again with use of the Lyappa, moved to the -X port.

American experiments activated. Thagard activated the American equipment inside Spektr, including two freezers for biomedical sample storage. On June 12 he began transferring previously collected samples to the freezers.⁶¹

Sixth EVA plans abandoned. After several discussions of an EVA to correct solar array problems on Spektr and Kvant 2, and to inspect the -Z port seal, NASA and RSA officials abandoned the plans for this mission. Reasons cited were insufficient planning time for the activities and lack of the proper tools for the solar array work. The two agencies jointly decided that there would still be enough power for the upcoming Atlantis docking and announced that launch of Atlantis on the STS-71 mission would take place on June 23.^{62,63} In the meantime, joint work on the creation, testing, and certification of new tools began. The Mir 19 crew was trained in the use of these tools before their launch to the station.⁶⁴

Mir 18 crew prepares for departure. Dezhurov, Strekalov, and Thagard began to prepare for their return to Earth, packing up experiments, biomedical samples, and other items to take back aboard Atlantis. They also concentrated on microgravity countermeasure exercises and spent time in the Chibis suit to prepare their cardiovascular systems for return to normal gravity.⁶⁵

Orbiter Docking System

For the docking at the Mir complex, a new Orbiter Docking System (ODS) had been installed on Atlantis on March 13. Although similar in design and operation to the docking system used for the Apollo-Soyuz Test Project in 1975⁶⁶, this docking system (fig. 6) is more complex, having more capability to accommodate larger space structures with greater center of gravity offset. The ODS structure can withstand 1000 kg of axial loads in the docked mode. The system weighs over 3500 lb, is 15 ft wide, 6.5 ft long, and 13.5 ft high. Mounted in Atlantis's payload bay, it includes a docking mechanism mated to a docking base attached to an external airlock, all of which is supported by a truss structure.⁶⁷ A camera is mounted on the center line of the system to transmit television images of the Kristall docking port during Atlantis's approach as an aid to the Atlantis commander during the manual phase of docking.⁶⁸

The 632-lb docking mechanism is an androgynous peripheral assembly system (APAS) built by RSC Energia in Russia and purchased for NASA by Rockwell International. The unit is alternately referred to as an androgynous peripheral docking assembly or system (APDA or APDS). The mechanism, based on a concept developed for the Buran space shuttle, will connect to the APAS-89 unit on the Kristall module.⁶⁹ It includes a capture ring and three guide petals, each with two capture latches. The capture ring is mounted to a base ring by six ball-screw shock absorbers that allow 6-degrees-of-freedom movement of the ring, and serve to damp out residual motion after capture, or soft docking. Twelve structural hooks on the base ring secure the mechanism to the docking unit on the other vehicle. The guide petals interact with those on the target APAS to align the two systems. After capture, the latches on the guide petals secure the two units, which are sealed by redundant silicone rubber O-rings. In the undocking procedure the latches are disengaged by a control switch on the Orbiter flight deck, and the two units are slowly pushed apart by preloaded springs.⁷⁰

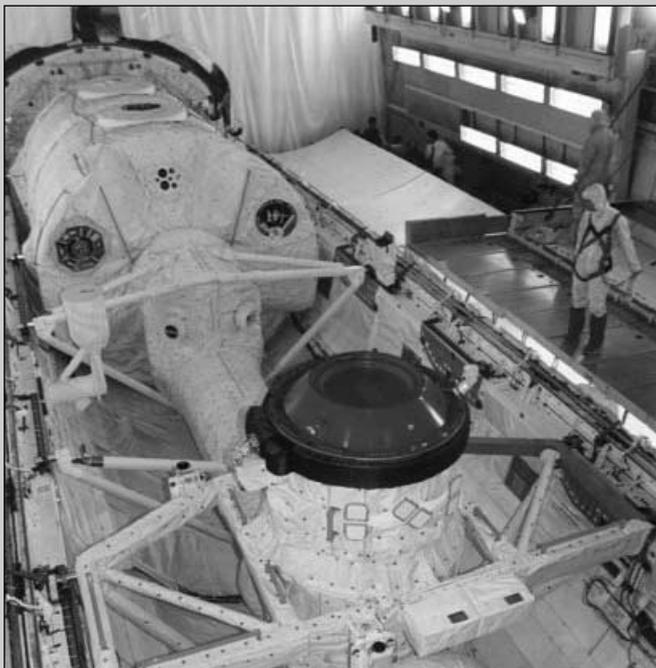
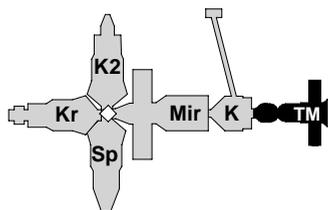


Figure 6. Orbiter Docking System is shown mounted in the payload bay of Atlantis. The dark circular structure in the foreground covers the androgenous peripheral assembly system, mounted on the docking base that protrudes from the supporting truss.

June 10-29, 1995



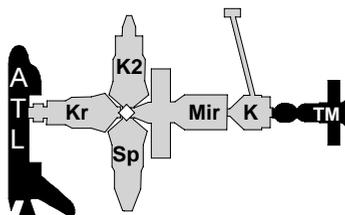
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Atlantis launched on STS-71 mission. After 4 days of delays caused by bad weather at Kennedy Space Center, Atlantis was launched on June 27 at 3:32 p.m. EDT. About 3 hr after launch, Gibson began a series of orbital maneuvering system (OMS) firings that would, through the next 2 days, take Atlantis to Mir's orbit, gradually decreasing the closing rate as well as the distance.⁷¹ On the second mission day, as they moved toward the station, Gibson, Precourt, and Dunbar began activating the Spacelab module in preparation for life sciences investigations. The crew extended the ODS docking ring to the docking position and found it in excellent working order.⁷²

Rendezvous techniques. After Gibson fired the terminal initiation burn, Atlantis was in a position to close in on Mir along the R-bar, or the line of the radius vector from Mir's center of mass to Earth. (The R-Bar approach had been successfully tested by Atlantis in retrieval of the German Crista-Spas satellite on STS-66 in November of 1994.) In this approach, gravity serves to slow the Orbiter's advance, thus reducing the need for jet firings and possible damage to Mir's solar arrays.⁷³ Atlantis jet firings in close proximity with Mir were done in low-Z with the use of jets on the nose and tail that, because of their offset position, would not fire directly at Mir. For Mir's part, its solar arrays were turned edge-on to minimize the effect of plumes. As Atlantis completed its final approach maneuvers, Mir's attitude was adjusted so that Kristall was in the correct docking position. At about 8 nmi below the station, Gibson took manual control of approach maneuvers, stopping at a distance of 250 ft from Mir to await a "go" for docking from ground controllers of both nations.⁷⁴

Dual ground control teams. Prefiguring the cooperation needed for ISS missions, a team of NASA flight controllers worked with TsUP controllers as consultants on Space Shuttle Orbiter systems and as liaisons between the U.S. and Russian ground support teams. In Houston, Russian flight controllers served similar functions in the NASA Mission Control Center. NASA Administrator Dan Goldin and RSA Director General Yuri Koptev, along with other Russian dignitaries, observed the docking from the TsUP.

June 29 - July 4, 1995



A Kvant 2
t - Kristall - Mir - Kvant - Soyuz-TM 21
l Spektr

Historic docking. On June 29 at 13:00 UTC, Gibson guided Atlantis to the docking port on the Kristall module and Harbaugh engaged the docking mechanism. The two spacecraft met 216 nmi above the Lake Baykal region of Russia (fig. 7). After pressurization and leak checks of the vestibule airlock, the two crews met and exchanged greetings and congratulations. There were ten of them, the largest crew ever aboard a single complex. The docked Mir and Atlantis totaled 220 tons, a record for orbiting spacecraft mass.^{75,76}

STS-71 Mission Highlights

June 27-July 7, 1995

Commander Robert L. Gibson (5th flight)
 Pilot Charles J. Precourt (2nd)
 Mission Specialist Ellen S. Baker (3rd)
 Mission Specialist Bonnie J. Dunbar (4th)
 Mission Specialist Greg Harbaugh (3rd)
 Cosmonaut Anatoly Solovyev (4th)-ascent
 Cosmonaut Nikolai Budarin (1st)-ascent
 Cosmonaut Researcher Norm Thagard (5th)-descent

Highlights: On STS-71, part of the series of joint U.S.-Russian missions comprising Phase I of the International Space Station program, Atlantis was the first Space Shuttle Orbiter to dock with Mir. It was the 100th human space mission for the U.S., the 69th Space Shuttle flight, and the 16th Atlantis flight. Major mission objectives all had international aspects:

- First rendezvous and docking of a U.S. Space Shuttle Orbiter with the Mir complex
- Transport to space of the Mir 19 crew, cosmonauts Anatoly Solovyev and Nikolai Budarin
- Return to Earth of the Mir 18 crew
- Conduct of the Shuttle-Mir Science Program, comprised of 28 on-orbit investigations aboard the Orbiter's Spacelab and Mir
- Logistical resupply of the Mir

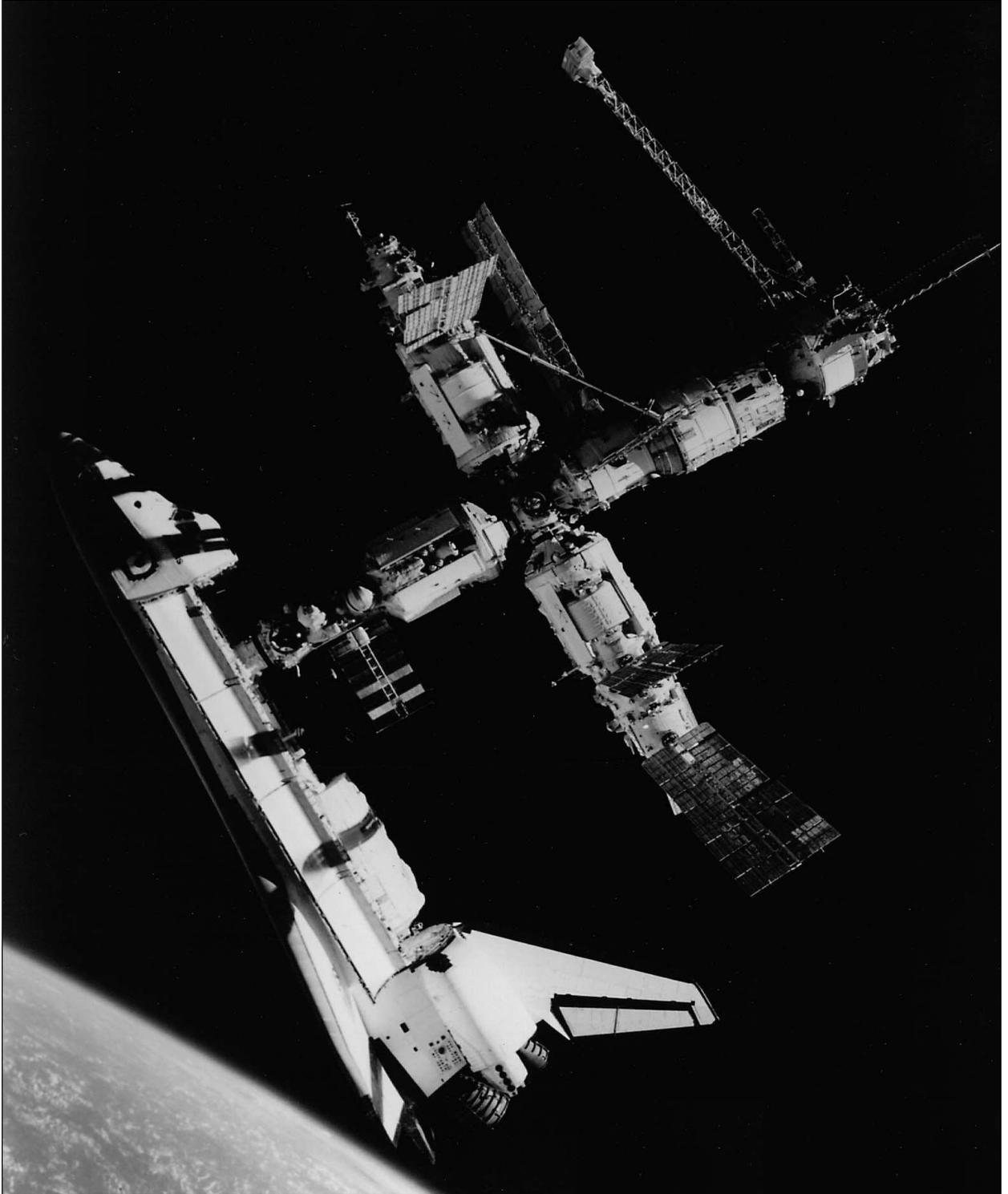


Figure 7. First docking of Atlantis with the Mir complex, during STS-71, June 29, 1995. Atlantis, with the aid of the new Orbiter Docking System, is docked with Kristall. Cosmonauts Solovyev and Budarin photographed the event from the temporarily undocked Soyuz-TM.